EFFECT OF INOCULATION AND FERTILIZATION ON THE GROWTH AND YIELD OF MUNGBEAN

BY

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CERTIFICATE

This is to certify that the thesis entitled "**Effect of Inoculation and Fertilization on the Growth and Yield of Mungbean**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy, embodies the result of a piece of bonafide research work carried out by Mohammad Shofayel Hossain, Registration number: 00968 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to find out the effect of inoculation and fertilization on the growth and yield of mungbean. The variety BARI mung 5 was used as the test crop. The experiment consist fourteen treatments. Data on different yield contributing characters and yield were recorded to study the effect of inoculation and fertilization. At 50 DAS, the tallest plant (80.43 cm) was recorded from T_{14} and the shortest (43.35 cm) was recorded from T_1. The same trends were followed at 20 DAS, 30DAS and 40 DAS. The maximum number of nodules per plant (22.60) was recorded from $T_{14,}$ whereas the minimum (13.20) was recorded from $T_{1.}$ Maximum total dry matter per plant was recorded from T_{14} and where bio-fertilizer and chemical fertilizer used but closely followed by bio- fertilizer without urea. There was trend to increase crop growth rate with the advancement of days from 40-50 DAS. There were no significant difference between treatment T_{14} and T_{13} where rhizobium used in both treatments. Yield attributes such as branches plant^{-1}, pods plant^{-1}, length of pod and seeds pod^{-1} was recorded maximum from the treatments rhizobium with NPK or MP combination. But single application of urea or TSP or MP showed similar trend with no fertilizer when lowest yield attributes were found. Seed weight also showed similar behavior. Seed yield showed maximum yield from bio-fertilizer and NPK combination while, it was closely followed by bio-fertilizer with PK and NPK fertilizer combination. Stover yield also followed similar pattern as in seed yield. From above discussion it is found that Urea could be substituted by rhizobium but P and K needs to be applied for higher seed yield.

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Chapter 1

INTRODUCTION

Pulse crops occupy a unique position in agriculture belongs to grain legumes. Among the various pulse; lentil, mungbean, blackgram, chickpea, grasspea and cowpea are very important. Pulse crop is an important food crops because it provides a cheap source of easily digestible dietary protein. According to FAO (1999) a minimum intake of pulse by a human should be 80 g per head per day, whereas it is only 14.19 g in Bangladesh (BBS, 2005).

Among the pulse crops, mungbean (*Vigana radiata* L.) is one of the most important pulse crops in Bangladesh with good digestibility, flavor, and high protein content. Mungbean grain contains 51% carbohydrates, 26% protein, 10% moisture, 4% mineral and 3% vitamins (Khan, 1981; Kaul, 1982). The green plants can also be used as animal feed and its residues can be used as green manure. Being a short duration crop it fits well into the existing cropping system (Ahmed *et al.*, 1978).

Mungbean is potentially useful legume crop which can improve the existing cropping pattern. Mungbean can also fix atmospheric nitrogen through the symbiotic relationship between the host mungbean roots and soil bacteria which can improves soil fertility. It may play an important role to supplement protein in the cereal-based low-protein diet of the people of Bangladesh, but the acreage and production of mungbean is steadily declining (BBS, 2005). However, it is one of the least cared crops. Mungbean is cultivated with minimum land preparation and without fertilizer application even without insect, diseases or weed control. All these factors are responsible for low yield of mungbean.

Cultivation of high yielding varieties of wheat and winter rice has occupied considerable land which is suitable for mungbean cultivation. Beside these, low yield potentiality of the crop is responsible for declining the area and production. At present the area under pulse crops is 0.38 million hectares with a production of 0.31 million tones where mungbean is cultivated in the area of 0.108 million hectares in Bangladesh (BBS, 2005) and the average yield is 0.81 t ha^{-1} (BBS, 2007) which is very poor in comparison to mungbean growing countries in the world. There are many reasons for low yield of mungbean in Bangladesh. The management of fertilizer is one of the important inputs that greatly affect the growth, development and yield of this crop.

Pulses fix nitrogen from the atmosphere, there is evident that application of nitrogenous fertilizers becomes helpful in increasing the yield (Patel *et al.*, 1984 and Ardeshana *et al.*, 1993). An adequate supply of nitrogen is essential for vegetative growth and desirable yield (Yoshizawa *et al.*, 1981).

Phosphorus is another important essential macro element for the normal growth and development of plant. The phosphorus requirements vary depending upon the nutrient content of the soil (Bose and Som, 1986). Phosphorus restricted the plant growth and remains immature (Hossain, 1990). So, phosphorus should be applied in the field for increasing the tissue content without enhancing smooth biomass accumulation (Santos *et al.*, 2004).

Potassium plays a remarkable role in plant physiological process. It is an essential constituent of different plant substances. Potassium deficiency causes yield reduction by limiting plant growth. It influences nutrient uptake by promoting root growth and nodulation. Mungbean is highly responsive to fertilizers and has a considerable response to potassium.

Now a day a number of organisms like *Rhizobium/Bradyrhzobium* have been identified for use as biological agent for fixing atmosphere nitrogen by symbiosis process with legume crops and making it available to the plants. To reduce the production cost and to fulfill the demand, more pulse production could be achieved through seed inoculation with *Rhizobium/Bradyrhzobium*. Franco (1978) reported that *Rhizobium/Bradyrhzobium* strains in association with the host plants were able to fix approximately 20% of the atmospheric nitrogen. In Bangladesh inoculation with *Rhizobium* increased 57% effective nodule, 77% dry matter production, 64% grain yield and 40% hay yield over unionculated control in mungbean (Chanda *et al.*, 1991). So, there is a large scope for utilizing the biological nitrogen fixing technology for obtaining more protein rich food from mungbean and also to improve nitrogen status of the soils of the country by selecting efficient use of mungbean inoculation.

The farmers of Bangladesh generally grow mungbean with minimum tillage and without fertilizer. There is an ample scope of increasing the yield of mungbean per unit area with improved management practices and by using proper fertilization. The farmers of our country do not use fertilizer in pulse crop due to their poor socio-economic condition which results low yield but it has great impact to increase yield. Adequate supply of chemical fertilizer or bio-fertilizer is essential for normal growth and yield of a crop.

Hence, the present experiment was taken to find out the response of nitrogen, phosphorus, potassium and *Rhizobium* on the performance of mungbean.

Considering the above circumstances, the present investigation has been undertaken with following objectives:

i. To study the effect of biofertilizer and chemical fertilizer on the growth and yield of mungbean.

ii. To determine the response of nitrogen, phosphorus, potassium and *Rhizobium* for attaining maximum growth relation to yield of mungbean.

iii. To study the effect of *Rhizobium* inoculation and chemical fertilizer combination for maximum growth and yield of mungbean.

Chapter 2

REVIEW OF LITERATURE

Mungbean is one of the important pulse crop in Bangladesh and as well as many countries of the world. The crop has less concentration by the researchers on various aspects because normally it grows without less care or management practices. For that a very few studies on the growth, yield and development of mungbean have been carried out in our country as well as many other countries of the world. The research work so far done in Bangladesh is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings related to the chemical and biofertilizer has been conducted at home and abroad on this crop have been reviewed in this chapter –

2.1 Effect of chemical fertilizers on the growth and yield of mungbean

A study was conducted by Nigamananda and Elamathi (2007) in Uttar Pradesh, India during 2005-06 to evaluate the effect of N application time as basal and as DAP (diammonium phosphate) or urea spray and plant growth regulator (NAA at 40 ppm) on the yield and yield components of green gram cv. K-851. The recommended rate of N:P:K (20:50:20 kg/ha) as basal was used as a control. Treatments included: 1/2 basal N + foliar N as urea or DAP at 25 or 35 days after sowing (DAS); 1/2 basal N + 1/4 at 25 DAS + 1/4 at 35 DAS as urea or DAP; and 1/2 basal N + 1/2 foliar spraying as urea or DAP + 40 ppm NAA. Results showed that 2% foliar spray as DAP and NAA, applied at 35 DAS, resulted in the highest values for number of pods/plant (38.3), seeds/pod, test weight, flower number, fertility coefficient, grain yield (9.66 q/ha).

Malik *et al.* (2006) conducted a field experiments in Faisalabad, Pakistan in 2000 and 2001 to evaluate the interaction effects of irrigation and phosphorus on greengram (*V. radiata* cv. NM-54). Five phosphorus doses (0, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) were arranged in a split-plot design with four replications. Phosphorus application at 40 kg P_2O_5 ha^{-1} affected the crop positively, while rates below and above this rate resulted in non-significant effects. Two irrigations and 40 kg P_2O_5 ha^{-1} were the most effective while rest of the combinations remained statistically non-significant to each other. It may be concluded that greengram can be successfully grown phosphorus at 40 kg P_2O_5 ha^{-1}.

Tickoo *et al.* (2006) carried out an experiment mungbean cultivars Pusa 105 and Pusa Vishal were sown at 22.5 and 30 m spacing and supplied with 36-46 and 58-46 kg NP/ha in a field experiment conducted in Delhi, India during the kharif season of 2000. Cultivar Pusa Vishal recorded higher biological and grain yield (3.66 and 1.63 t/ha, respectively) compared to cv. Pusa 105. NP rates had no significant effects on both the biological and grain yield of the crop.

Ijaz *et al.* (2005) conducted an experiment on the yield and yield components (pods per plant, seeds per pod and 1000-seed weight) of mungbean cv. *NM-92* and showed that P at 90 kg/ha gave the highest seed yield, pods per plant, seeds per pod and seed weight.

Bhat *et al.* (2005) conducted a study during the summer of 2004 in Uttar Pradesh, India, to examine the effects of phosphorus levels on greengram. Four phosphorus rates (0, 30, 60 and 90 kg/ha) were used. All the phosphorus rates increased the seed yield significantly over the control. The highest seed yield was observed with 90 kg P/ha, which was at par with 60 kg P/ha, and both were significantly superior to 30 kg P/ha. Likewise, 60 kg P/ha significantly improved the yield attributes except test weight compared to the control. The stover yield followed similar trend observed in seed yield.

A field experiment was conducted by Vikrant *et al.* (2005) on a sandy loam soil in Hisar, Haryana, India, during khatif 2000-01 and 2001-02 to study the effects of P (0, 20, 40 and 60 kg P_2O_5/ha) applications to greengram cv. Asha. Application of 60 kg P, being at par with 40 kg P, was significantly superior to 0 and 20 kg P/ha in respect of grain, stover and protein yields of green gram.

Oad and Buriro (2005) conducted a field experiment to determine the effect of different NPK levels (0-0-0, 10-20-20, 10-30-30, 10-30-40 and 10-40-40 kg/ha) on the growth and yield of mungbean cv. AEM 96 in Tandojam, Pakistan, during the spring season of 2004. The different NPK levels significantly affected the crop parameters. Fertilizer rate 10-30-30 kg NPK/ha was the best treatment, recording plant height of 56.25, germination of 90.50%, satisfactory plant population of 162, prolonged days taken to maturity of 55, long pods of 5.02 cm, seed weight per plant of 10.53 g, seed index of 3.52 g and the highest seed yield of 1205 kg/ha. There was no significant change in the crop parameters beyond this level.

Edwin *et al.* (2005) conducted a field experiment on greengram during pre-*kharif* season. Results showed that the highest number of branches per plant (3.23) was obtained with 30 kg Mussoorie rock phosphate (MRP) + 30 kg single superphosphate (SSP)/ha. SSP at 60 kg/ha gave the highest number of clusters per plant (4.36), pod length (7.34 cm), seeds per pod (10.46), 1000-seed weight (34.90 g) and seed yield (15.13 q/ha). Maximum plant height (31.20 cm), dry matter per plant (36.13 g/plant) and number of pods per plant (17.43) was obtained with 60 kg DAP ha^{-1}.

Subhendu *et al.* (2005) carried out a field experiment on summer greengram cv. *Pusa Baisakhi* and revealed that increase in the levels of P from 0 to 60 kg ha^{-1} increased the yield, nutrient uptake, gross and net return.

Khan *et al.* (2004) conducted a study on the yield components of mungbean cv. *NM-98* and revealed that the increase in phosphorus levels decreased the days to flowering and increased the branches per plant, number of pods per plant, 1000-grain weight and grain yield. The highest yield of 1022 kg/ha was obtained at the phosphorus level of 100 kg/ha compared to a 774-kg/ha yield in the control. However, the most economical phosphorus level was 40 kg/ha, because it produced a grain yield statistically comparable to 100 kg P/ha.

A field experiment was conducted by Manpreet *et al.* (2004) in Ludhiana, Punjab, India, during summer 2000 to investigate the response of mungbean genotypes (SML 134, SML 357 and SML 668) to P application (0, 20, 40 and 60 kg P_2O_5/ha) under irrigated conditions. Yield attributes such as number of branches per plant and pods per plant were significantly higher in SML 357 and SML 134, whereas pod length and 100-seed weight were higher in SML 668, which accounted for higher grain yield in this cultivar compared to SML 134 but was at par with SML 357. The straw yield showed the reverse trend with significantly higher value for SML 134, thus lowering the harvest index significantly compared to SML 668 and SML 357. P application showed a non-significant effect on number of branches per plant, number of seeds per pod, pod length and 100-seed weight. However, the increase in P level showed significant increase in the number of pods per plant, which accounted for significantly higher grain and straw yields at higher levels (40 and 60 kg/ha) compared to lower levels (0 and 20 kg/ha). Harvest index remained unaffected with P application. The economic optimum P level for all the 3 summer mungbean genotypes was found to be 46.1 kg P_2O_5/ha.

Nadeem *et al.* (2004) studied the response of mungbean cv. NM-98 to seed inoculation and different levels of fertilizer (0-0, 15-30, 30-60 and 45-90 kg N- P_2O_5 ha^{-1}) under field conditions. Application of fertilizer significantly increased the yield and the maximum seed yield was obtained when 30 kg N ha^{-1} was applied along with 60 kg P_2O_5 ha^{-1}.

Riaz *et al.* (2003) conducted an experiment on mungbean and were supplied with NPK at 50:0:0 (F_1), 50:100:0 (F_2) and 50:100:50 kg/ha (F_3) and revealed that no significant differences in the number of pods per plant, number of grains per plant, grain yield and straw yield were observed in plants under F_2 and F_3. F_3 resulted in the highest grain yield value and costs, and lowest net field benefit.

Mozumder *et al.* (2005) conducted an experiment to study the effect of different nitrogen levels viz. 0, 20, 40, 60 and 80 kg N ha^{-1} on Binamoog-2 and they observed that increase of nitrogen fertilizer increased seed yield up to 40 kg N ha^{-1} and that was 1607 kg ha^{-1}.

Malik *et al.* (2003) conducted an experiment to determine the effect of varying levels of nitrogen (0, 25, and 50 kg ha^{-1}) and phosphorus (0, 50, 75 and 100 kg ha^{-1}) on the yield and quality of mungbean cv. NM-98 in 2001. They observed that number of flowers per plant was found to be significantly higher by 25kg N ha^{-1}. Number of seeds per pod was significantly affected by varying levels of nitrogen and phosphorus. Growth and yield components were significantly affected by varying levels of nitrogen and phosphorus. A fertilizer combination of 25 kg N + 75 kg ha^{-1} resulted with maximum seed yield (1112.96 kg ha^{-1}).

Rajender *et al.* (2003) investigated the effects of N (0, 10, 20 and 30 kg P ha-1) and P (0, 20, 40 and 60 kg ha^{-1}) fertilizer rates on mungbean genotypes MH 85-111 and T44. Grain yield increased with increasing N rates up to 20 kg ha^{-1}. Further increase in N did not affect yield.

Satish *et al.* (2003) conducted an experiment in Haryana, India in 1999 and 2000 to investigate the response of mungbean cultivars Asha, MH 97-2, MH 85-111 and K 851 to different P levels (0, 20, 40 and 60 kg P_2O_5/ha). Results revealed that the highest dry matter content in the leaves, stems and pods was obtained in Asha and MH 97-2. The total above-ground dry matter as well as the dry matter accumulation in leaves, stems and pods increased with increasing P level up to 60 kg P/ha. MH 97-2 and Asha produced significantly more number of pods and branches/plant compared to MH 85-111 and K 851. P at 40 and 60 kg/ha increased the number of pods/plant, grain yield and grains per pod over the control and P at 20 kg/ha. The number of branches per plant increased with increasing P rates.

Yakadri *et al.* (2002) studied the effect of nitrogen (20, 40 and 60 kg ha^{-1}) on crop growth and yield of greengram (cv. ML-267). Application of nitrogen at 20 kg ha^{-1} resulted in the significant increase in leaf area ratios indicating better partitioning of leaf dry matter.

The effects of N (0, 10, 20 and 30 kg/ha) and P (0, 20, 40 and 60 kg/ha) on mungbean cultivars MH 85-111 and T44 were determined in a field experiment conducted by Rajender *et al.* (2002) in Hisar, Haryana, India during the summer of 1999-2000. The number of branches, number of pods per plant, number of seeds per pod, 100-seed weight and straw yield increased with increasing rates P, whereas grain yield increased with increasing rates of up to 40 kg P/ha only.

Mahboob and Asghar (2002) studied the effect of seed inoculation at different nitrogen levels on mungbean at the agronomic research station, Farooqabad in Pakistan. They revealed that various yield components like 1000 grain weight were affected significantly with 50-50-0 NPK kg ha^{-1} application. Again they revealed that seed inoculation +50-50-0 NPK kg ha^{-1} exhibited superior performance in respect of seed yield (955 kg ha^{-1}).

Srinivas *et al.* (2002) conducted an experiment on the performance of mungbean at different levels of nitrogen and phosphorus. Different rates of N (0, 25 and 60 kg ha^{-1}) and P (0, 25, 50 and 60 kg ha^{-1}) were tested. They observed that the number of pods per plant was increased with the increasing rates of N up to 40 kg ha^{-1} followed by a decrease with further increase in N. They also observed that 1000-seed weight was increased with increasing rates of N up to 40 kg ha^{-1} along with increasing rates of P was than followed by a decrease with further increase in N.

Two field experiments were conducted in Kalubia Governorate, Egypt, in 1999 and 2000 summer seasons by El-Metwally and Ahmed (2001) to investigate the effects of P levels (0, 15, 30 and 45 kg/feddan) on the growth, yield and yield components as well as chemical composition of mungbean cv. Kawmy-1. Growth, yield and yield components of mungbean were markedly improved with the addition of 45 kg P/feddan. Addition of 45 kg P/feddan markedly increased total carbohydrate and protein percentages compared with other treatments. Application of 45 kg P/feddan markedly increased the number of pods per plant. Addition of 30 kg P/feddan was the recommended treatment to obtain the best results for growth, yield and yield components as well as chemical composition of mungbean.

A field experiment was carried out by Sharma and Sharma (1999) during summer seasons at Golaghat, Assam, India. Mungbean was grown using farmers practices (no fertilizer) or using a combinations of fertilizer application (30 kg N + 35 kg P_2O_5 ha^{-1}). Seed yield was 0.40 ton ha^{-1} with farmer's practices, while the highest yield was obtained by the fertilizer application (0.77 ton ha^{-1}).

Mandal and Sikder (1999) conducted a greenhouse pot experiment on mungbean cv. BARI Mung-5 under different N rates (0, 20 and 30 kg ha^{-1}). They noted that the seed yield increased (700, 800 and 900 kg ha^{-1}) significantly with increased N application, respectively.

Karle and Pawar (1998) examined the effect of varying levels of N and P fertilizers on summer mungbean. They reported that mungbean produced higher seed yield in with the application of 15 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}.

Thakur *et al.* (1996) conducted an experiment with greengram (*Vigna radiata*) grown in kharif [monsoon] 1995 at Akola, Maharashtra, was given 0, 25, 50 or 75 kg P_2O_5/ha as single superphosphate or diammonium phosphate. Seed and straw yields were not significantly affected by P source, and seed yield averaged 0.91, 1.00, 1.24 and 1.13 t/ha at the 4 P rates, respectively. P uptake was also highest with 50 kg P_2O_5/ha.

Kaneria and Patel (1995) conducted a field experiment on a Vartisol in Gujarat, India with mungbean cv. K 581 using 0 or 20 kg N ha^{-1}. They found that application of 20 kg N ha^{-1} increased the seed yield (1.14 ton ha^{-1}) when compared with that of control (1.08 ton ha^{-1}).

In a field experiment was conducted by Patro and Sahoo (1994) during the winter season of 1991 at Berhampur, Orissa, mung beans cv. Dhauli and PDM 54 given 0, 15, 30, 45 or 60 kg P_2O_5/ha gave seed yields of 706, 974, 1049, 1234 and 1254 kg/ha, respectively. Yield was not significantly different between cultivars.

Bachchhav *et al.* (1994) conducted a field experiment during the summer season with greengram cv. Phule-M. They observed that seed yield increased with 30 kg N ha^{-1} among nitrogen fertilizers rates (0-45 kg N ha^{-1}).

Ardeshana *et al.* (1993) conducted a field experiment on clay soil during the rainy season of 1990 to study the response of mungbean to nitrogen. They observed that seed yield increased with application of nitrogen fertilizer up to 20 kg N ha^{-1} in combination with phosphorus fertilizer up to 40 kg P_2O_5 ha^{-1}.

Singh *et al.* (1993) examined the effects of varying levels of N on mungbean cv. MH-85-61. They found that nitrogen application at the rate of 30 kg N resulted in the highest seed yield in mungbean.

Tank *et al.* (1992) found that mungbean fertilized with 20 kg N along with to level of 40 kg P_2O_5 ha^{-1} increased seed yield significantly over the unfertilized control. They also reported that mungbean fertilized with 20 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant.

Chawdhury and Rosario (1994) studied the effect of 0, 30, 60 or 90 kg N ha^{-1} levels on the rate of growth and yield performance of mungbean at los Banos, Philippines in 1988. They observed that N above the rate of 30 kg N ha^{-1} reduced the dry matter yield. Leelavathi *et al.* (1991) showed significant increase in seed yield of mungbean by N 60 kg N ha^{-1}. While in another study Sarkar and Banik (1991) also reported that seed yield of mungbean increased significantly using 60kg N ha^{-1}.

A field experiments was conducted by Sarkar and Banik (1991) to study the effect of N and P on yield of mungbean. Results showed that maximum seed yield was obtained with the combination of 20 kg N and 60 kg P_2O_5 ha^{-1}.

Suhartatik (1991) in a study observed that increased application of NPK fertilizers significantly increased the plant height of mungbean.

Bali *et al.* (1991) conducted a field trial one mungbean in kharif seasons on silty clay loam soil. They revealed that 1000 seed weight increased with 40 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}.

Arya and Kalra (1988) reported that application of N at the rate of 50 kg ha^{-1} along with 50 kg P ha^{-1} increased mungbean yield. Results from field experiments conducted by Mahadkar and Saraf (1988) during summer season of mungbean showed that the application of N with P and K at 20:25 kg ha^{-1} gave higher seed yield.

Hamid (1988) conducted a field experiment to investigate the effect of nitrogen and carbon on the growth and yield performance of mungbean (*Vigna radiate* L. wilczek). He found that the plant height of mungbean cv. Mubarik was found to be increased nitrogen at 40 kg ha^{-1}.

Results of an experiment, conducted by Sardana and Verma (1987) in Delhi, India, revealed that application of nitrogen, phosphorus and potassium fertilizers in combination resulted in significant increase in plant height of mungbean. They also stated that the application of nitrogen, phosphorus and potassium fertilizers in combination resulted in the significant increase in seed yield of mungbean. They also stated that application of nitrogen, phosphorus and potassium fertilizers combinedly resulted in significant increases in thousand seed weight of mungbean.

Salimullah *et al.* (1987) reported that the number of pods per plant was highest with the application of 50 kg N ha^{-1} along with 75 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1} in summer mungbean.

Patel and Parmer (1986) conducted an experiment of the response of greengram to varying levels of nitrogen and phosphorus. They observed that increasing N application to rainfed mungbean (cv. Gujrat-1) from 0 to 50 kg N ha^{-1} increased the number of pods per plant.

In trials, on clay soils during the summer season Patel *et al.* (1984) observed the effect of N levels (0, 10, 20 and 30 kg N ha^{-1}) and that of the P (0, 10, 20, 40, 60 and 80 kg P_2O_5 ha^{-1}) on the growth and seed yield of mungbean. It was found that application of 30 kg N ha^{-1} along with 40 kg P_2O_5 ha^{-1} significantly increased the number of pods per plant. They observed that application of 40 kg P_2O_5 ha^{-1} along with 20 kg N ha^{-1} significantly increased the 1000-seed weight of mungbean.

In an experiment, Yien *et al.* (1981) applied nitrogen and phosphorus fertilizers to mungbean and reported that combined application of nitrogen and phosphorus fertilizers increased the number of pods per plant. The rate of nitrogen and phosphorus was 50 kg and 75 kg per hectare, respectively. Combined application of nitrogen and phosphorus significantly increased the dry weight of plants. Combination with 20 kg P ha^{-1} resulted in significant increase in the seed yield.

2.2 Effect of *Rhizobium* on the growth and yield of mungbean

Mozumder *et al.* (2005) conducted an experiment on mungbean to evaluate the response of summer mungbean cultivars *Binamoog-2* and *Kanti* to *Bradyrhizobium* inoculation and N application. Results showed that the highest seed yield (1461 kg ha^{-1}) were obtained in the treatment with 40 kg N^{-1} ha along with *Bradyrhizobium* inoculation but straw yield (4702 kg ha^{-1}) was maximum from 60 kg N ha^{-1} with *Bradyrhizobium* inoculation.

Dost *et al.* (2004) conducted a field experiment on mungbean cv. *NM-92* and revealed that the maximum number of pods (17.0) were recorded at 80 kg $P_2O_5^{-1}$ ha^{-1} + *Rhizobium* inoculum and the number of grains per pod increased only with an increase of P levels. The maximum grains per pod (10.9) were recorded at 80 kg P_2O_5 ha^{-1} followed by 10.83 at 65 kg P_2O_5 ha^{-1} and the highest grain yield (1018 kg ha^{-1}) from the combination of 65 kg O_5 ha^{-1} and *Rhizobium* inoculum.

Duary *et al.* (2004) conducted a study on greengram and showed that *Rhizobium,* 10 kg N ha^{-1}, 30 kg P ha^{-1}, 30 kg K ha^{-1}, 20 kg S ha^{-1} produced the significantly highest seed yield.

Bhattacharyya and Pal (2001) conducted a field experiment on summer greengram and showed that *Rhizobium* inoculation and application of P significantly influenced the number of nodules per plant, dry matter accumulation in the shoot, crop growth rate and plant height. Maximum growth was obtained in *Rhizobium* treatments combined with P at 40 kg ha^{-1}.

Raju and Verma (1984) carried out a field experiment during summer season of 1979 and 1980 to study the response of mungbean var. Pusa Baishaki to varying levels of nitrogen (15, 30, 45 and 60 kg N ha^{-1}) in the presence and absence of seed inoculation with *Rhizobium.* They found that maximum dry matter weight per plant was obtained by the application of 60 kg N ha^{-1} inoculated with *Rhizobium.*

Sattar and Ahmed (1995) carried out a field experiment on mungbean inoculation with *Rhizobium* inoculation and observed that *Rhizobium* inoculation increased plant height compared to control.

Upadhyay *et al.* (1999) found that seed yield of mungbean was higher when the seeds were inoculated with *Rhizobium* (2.02 vs. 1.87 t ha^{-1}). Provorov *et al.* (1998) stated that seed inoculation of mungbean increased the seed yield by 38.2% over uninoculated control.

Shukla and Dixit (1996) conducted a field experiment where *Vigna radiata* cv. Pusa Baishakhi was seed inoculated with *Rhizobium* or not inoculated and given 0-60 kg P_2O_5 ha^{-1}. They found that seed inoculation increased seed yield of the crop.

Rahman (1993) reported that seed inoculation of *Rhizobium* to *Vigna radiata* cv. Kanti increased plant height.

Chawdhury and Rosario (1994) stated that seed inoculated with *Rhizobium* increased the seed yield of mungbean. Jat and Rathore (1994) reported that inoculation of greengram seed with *Rhizobium* gave increased seed yield.

Ardeshna *et al.* (1993) noted that seeds of mungbean inoculated with *Rhizobium* significantly increased the number of pods $plant^{-1}$ compared with uninoculated control.

Gill *et al.* (1985) observed that inoculation of seed with *Rhizobium* significantly increased the number of pods $plant^{-1}$ of mungbean.

Khurana and Poonam (1993) studied with *Rhizobium* strains (LMR 107, KM 1, M 10, GMBS 1 and MO 5) and *Vigna radiata* cv. ML 207 and P 516. Under field condition seed inoculation with *Rhizobium* strain increased the seed yield by 21.5% and 35.1% over uninocultated control in 1988 and 1989, respectively.

Hoque (1991) reported that the *Rhizobium* strain of Bangladesh Agricultural University, Mymensingh, showed 20-60% increased in seed yield of mungbean when inoculated seeds were sown.

Chapter 3

MATERIALS AND METHODS

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of inoculation and fertilization on the growth and yield of mungbean. The details materials & methods are presented below under the following headings -

3.1 Experimental site

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated in $23^{0}74'$N latitude and $90^{0}35'$E longitude (Anon., 1989).

3.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) shallow red brown terrace soil under AEZ No. 28. The selected experimental plot was medium high land and the soil series was Tejgaon (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka and presented in Appendix I.

3.3 Climate

The climate of experimental site was subtropical, characterized by three distinct seasons, the winter (rabi) season from mid October to mid March and the pre-monsoon (kharif-I) period or hot season from mid March to mid April and the monsoon period (kharif-ii) from mid May to mid October. (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the period of the experiment at site was collected from the Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and presented in Appendix II.

3.4 Planting material

The variety BARI mung-5 was used as the test crop. The seeds were collected from the Pulse Seed Division of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. BARI mung-5 is a recommended variety of mungbean, which was developed by the national seed board. It grows both in kharif and rabi season. Crop duration ranges from 60 to 65 days and seed yield ranges is 1.1-1.4 ton/ha.

3.5 Land preparation

The land was irrigated before ploughing. After having zoe condition the land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 19 February 2007. Experimental land was divided into unit plots as per design of the experiment.

3.6 Treatments of the experiment

The treatments of the experiment are as follows:

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* inoculant (30 gm kg^{-1} seed)
T_9: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30 gm kg^{-1} seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30 gm kg^{-1}seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

3.7 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 36.5 m × 12.0 m was divided into three equal blocks. Each block was divided into 14 plots where 14 treatments were allotted at random. There were 42 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The distance maintained between two blocks and two plots were 1.5 m and 0.75 m respectively.

3.8 Sowing of seeds in the field

The seeds of mungbean were sown on 04 April, 2007. Seeds were treated with Bavistin before sowing the seeds to control the seed borne disease. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm. Row to row distance was 30 cm.

3.9 Intercultural operations

3.9.1 Thinning

Seeds were germinated by four days after sowing (DAS). Thinning was done twice; first thinning was done at 8 DAS and second was done at 15 DAS to maintain proper plant population having 10 cm between plants in each row in each plot.

3.9.2 Irrigation and weeding

Three irrigations were applied thrice. The crop field was weeded twice; first weeding was done at 15 DAS and second at 30 DAS.

3.9.3 Plant protection against insect and pest

At early stage of growth, few worms (*Agrotis ipsilon*) and virus vectors (Jassid) attacked the young plants and at later stage of growth, pod borer (*Maruca testulalis*) attacked the plant. Marshal was sprayed at the rate of 1litre ha^{-1}.

3.10 Crop sampling and data collection

Ten plants from each treatment plot were randomly sampled and marked with sample tag. The data of plant height, number of leaves per plant was recorded at an interval of 10 days which was started from 20 DAS. Besides, number of nodules per plant, pod per plant, pod length, number of seeds per pod, 1000 seed weight and yield at the time of harvest was recorded.

3.11 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown to black in color. The matured pods were collected by hand picking from a pre demarcated area of seven linear at the center of each plot.

3.12 Data collection

The following data were recorded:

i. Plant height (cm)
ii. Number of leaves per plant
iii. Total dry matter (g)
iv. Crop Growth Rate (CGR)
v. Relative Growth Rate (RGR)
vi. Number of nodules per plant
vii. Number of branches per plant
viii. Number of pods per plant
ix. Pod length (cm)
x. Number of seeds per pod
xi. 1000- seed weight (g)
xii. Seed yield (t ha^{-1})
xiii. Stover yield (t ha^{-1})
xiv. Biological yield
xv. Harvest index

3.13 Procedure of data collection

3.13.1 Plant height (cm)

The heights of plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot starting from 20 DAS to 50 DAS at 10 days interval.

3.13.2 Number of leaves per plant

The leaves (trifoliate) were counted from selected plants. The average number of leaves per plant was determined. Data were recorded from average of 10 plants selected at random from the inner rows of each plot starting from 20 DAS to 50 DAS at 10 days interval.

3.13.3 Number of nodules per plant

The number of nodules in each plant was recorded from randomly selected plant at the time of flower initiation. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.13.4. Estimated growth parameter

3.13.5 Total dry matter

Ten plants were collected randomly, from each plot at 10 days interval starting from 20 days after sowing (DAS). Plants including roots, stem, pods and leaves were oven dried at 70^0C for 72 hours than transferred into desicator and allowed to cool down to the room temperature. Afterwards final weight was taken and converted into dry weight per plant.

Crop Growth Rate (CGR)

Crop growth rate was calculated using the following formula-

$$CGR = \frac{1}{GA} \times \frac{W_2\text{-}W_1}{T_2 T_1} \quad g\ m^{-2}\ day^{-1}$$

Where,

GA = Ground area (m^2)

W_1 = Total dry weight at time T_1 (g)

W_2 = Total dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

Relative Growth Rate (RGR):

Relative growth rate was calculated using the following formula

$$RGR = \frac{LnW_2 - LnW_1}{(T_2\text{-}T_1)} \quad g\ g^{-1}\ day^{-1}$$

Where,

W_1 = Total dry weight at time T_1 (g)

W_2 = Total dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

L_n = Natural logarithm.

3.13.6 Number of branches per plant

Number of branches of selected plants from each plot was counted and the mean number was expressed as per plant basis. Data were recorded at the time of final harvest.

3.13.7 Number of pods per plant

Number of total pods of selected plants from each plot. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.13.8 Pod length

Pod length of selected plants was taken from each plot. Data were recorded as the average of 10 pods selected at random from the inner rows plant of each plot.

3.13.9 Number of seeds per pods

The number of seeds in each pod was also recorded from randomly selected pods at the harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.13.10 Weight of 1000-seed

One thousand cleaned dried seeds were counted randomly from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.13.11 Seed yield per hectare

The seeds collected from 2.1 m^2 of each plot were sun dried properly. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.13.12 Stover yield per hectare

The Stover collected from 2.1 m^2 of each plot was sun dried properly. The weight of stray was taken and converted the yield in t ha^{-1}.

3.13.13 Harvest index

The harvest index was calculated by using the following formula

$$\text{Harvest Index (\%)} = \frac{\text{Seed Yield}}{\text{Biological Yield}} \times 100$$

3.14 Statistical analysis

The mean values of all the characters were calculated and analysis of variance was performing by the 'F' (variance ratio) test. The means were separated following Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

RESULTS AND DISCUSSION

The present study was conducted to determine the effect of inoculation and fertilization on the growth and yield of mungbean. Data on different yield contributing characters and yield were recorded to study the effect of inoculation and fertilization on the growth and yield components and yield of mungbean. The analysis of variance (ANOVA) of the data on different yield components and yield are given in Appendix III-IX. The findings have been presented and discussed, with proper interpretations under the following headings.

4.1 Plant height

Plant height of mungbean varied significantly due to the different treatments at 20, 30, 40 and 50 DAS (Appendix III). At 20 DAS, the maximum plant height (36.81 cm) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (33.92 cm, 32.35 cm, 31.12 cm) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_{12} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), respectively. On the other hand the minimum plant heigt (19.33 cm) was recorded from T_1 (control) which was closely followed (21.54 cm, 22.11 cm and 24.75 cm) by T_3 (TSP: 80 kg ha^{-1}), T_2 (Urea: 45 kg ha^{-1}) and T_4 (MP: 55 kg ha^{-1}), respectively (Table 1). At 30 DAS the maximum plant height (51.15 cm) was recorded from T_{14} which was statistically similar with T_{13} (48.27 cm), T_{12} (47.17 cm), T_{10} (45.24 cm), T_{11} (44.70 cm) and T_7 (43.82 cm), while the shortest plant (30.56 cm) was recorded from T_1 which was closely followed by T_2 (33.98 cm) and T_3 (35.98 cm). At 40 DAS, the maximum plant height (68.03 cm) was recorded from T_{14} which was statistically similar with T_{13} (64.10 cm), T_{12} (59.85 cm), T_{11} (59.44 cm) and T_{10} (59.24 cm). The minimum plant height (34.28 cm) was recorded from T_1 which was closely followed by T_3 (45.61 cm) and T_2 (46.74 cm).

Table 1. Effect of inoculation and fertilization on plant height of mungbean

Treatments	Plant height (cm)			
	20 DAS	30 DAS	40 DAS	50 DAS
T_1	19.33 g	30.56 e	34.28 f	43.35 e
T_2	22.11 e-g	33.98 de	46.74 de	49.93 de
T_3	21.54 fg	35.98 c-e	45.61 e	51.55 de
T_4	24.75 d-g	40.06 b-d	49.46 c-e	57.03 cd
T_5	28.31 b-d	42.67 bc	57.11 bc	70.40 ab
T_6	26.59 c-f	43.04 bc	55.66 b-d	66.57 bc
T_7	31.12 a-c	43.82 a-c	58.18 bc	71.90 ab
T_8	26.49 c-f	41.81 bc	55.96 b-d	69.11 a-c
T_9	27.66 c-e	42.51 bc	57.20 bc	70.03 ab
T_{10}	29.57 b-d	45.24 ab	59.24 a-c	70.48 ab
T_{11}	29.88 b-d	44.70 ab	59.44 a-c	70.89 ab
T_{12}	32.35 a-c	47.17 ab	59.85 a-c	67.58 a-c
T_{13}	33.92 ab	48.27 ab	64.10 ab	76.01 ab
T_{14}	36.81 a	51.15 a	68.03 a	80.43 a
$S\bar{x}$	1.835	2.431	3.025	3.918
CV(%)	11.40	9.98	9.55	10.38

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMRT

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* (30gm kg^{-1}seed) inoculant
T_9: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30gm kg^{-1}seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30gm kg^{-1}seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30gm kg^{-1}seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

At 50 DAS the tallest plant (80.43 cm) was recorded from T_{14} which was statistically similar with T_{13} (76.01 cm), T_7 (71.90 cm), T_{11} (70.89 cm), T_{10} (70.48 cm), T_5 (70.40 cm) and T_9 (70.03 cm). In all the stages of the plant growth, treatment T_1 produced lower plant height where fertilizer & inoculation was not used.

Among the different combination, *Rhizobium* with recommendation dose of fertilizer was more effective for the vegetative growth of mungbean as found maximum plant height. The trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. NPK fertilizer as recommended also effective for plant growth under the trial. On the other hand control gave the lowest plant growth with shortest plant. Different combination of NPK fertilizer followed this trend. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1984), Werakonphanit *et al.* (1979), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Sattar and Ahmed (1995), Khurana and Poonam (1993).

4.2 Number of leaves per plant

Significant variation was recorded for number of leaves per plant of mungbean by different treatments at 20, 30, 40 and 50 DAS (Appendix IV). At 20 DAS, the maximum number of leaves per plant (9.48) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (8.69, 8.60 and 8.44) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and T_{12} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}), respectively. Again the minimum number of leaves per plant (4.78) was recorded from T_1 (control) which was closely followed by T_3, T_2, T_4, T_6 &T_8 respectively (Table 2). The maximum number of leaves per plant (16.35) was recorded from T_{14} which was statistically similar with T_{13} (15.82), T_{10} (15.48), T_{11} (15.38), T_{12} (15.33) and T_7 (15.09). On the other hand the minimum number of leaves per plant (12.87) was recorded from T_1 which was closely followed by T_3 (14.13) at 30 DAS. At 40 DAS, the maximum number of leaves per plant (21.56) was recorded from T_{14} which was statistically similar with T_{13} (20.51), T_{10} (20.00), T_7 (19.92) and T_{11} (19.74). While lower number of leaves per plant was recorded from T_1. At 50 DAS the maximum number of leaves per plant (25.95) was recorded from T_{14} which was statistically similar with T_{13} (24.84), T_9 (24.51) and T_7 (24.40), while significantly lowest number of leaves per plant (19.67) was recorded from T_1. Without fertilizer & rhizobium showed the lowest number of leaves per plant in all the growth stages.

Among the different combination, *Rhizobium* with recommended doses of fertilizer was more effective for the vegetative growth of mungbean as a result maximum number of leaves per plant was observed. This trend was similar or followed by the combination of *Rhizobium* and NPK fertilizer. NPK fertilizers, as recommended dose was also equally effective for plant growth and development under the trial. On the other hand control treatment gave the lowest growth of plant. Different combination of NPK fertilizer followed this trend. Sole application of NPK fertilizer was equally effective as in *Rhizobium*. This findings was supported by Sardana and Verma (1987), Salimullah *et al.* (1987), Patel *et al.* (1992), Werakonphanit *et al.* (1979), Dost *et al.* (2004), Vikrant (2005), Raman and Venkataramana (2006), Malik *et al.* (2006), Nigamananda and Elamathi (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993), Oad and Buriro (2005).

Table 2. Effect of inoculation and fertilization on number of leaves per plant of mungbean

Treatments	Number of leaves per plant			
	20 DAS	30 DAS	40 DAS	50 DAS
T_1	4.78 f	12.87 d	16.11 d	19.67 g
T_2	5.70 d-f	14.70 bc	19.14 bc	22.70 de
T_3	4.95 ef	14.13 cd	18.21 c	21.18 f
T_4	5.83 d-f	14.40 bc	18.50 c	21.78 ef
T_5	7.45 a-d	14.70 bc	19.66 bc	24.14 b-d
T_6	6.37 c-f	14.80 a-c	19.29 bc	22.87 c-e
T_7	8.60 a-c	15.09 a-c	19.92 a-c	24.40 a-c
T_8	6.71 b-f	14.41 bc	19.48 bc	23.52 b-d
T_9	7.05 b-e	14.61 bc	19.58 bc	24.51 a-c
T_{10}	7.48 a-d	15.48 a-c	20.00 a-c	23.73 b-d
T_{11}	7.70 a-d	15.38 a-c	19.74 a-c	23.48 b-d
T_{12}	8.44 a-c	15.33 a-c	19.56 bc	23.29 b-e
T_{13}	8.69 ab	15.82 ab	20.51 ab	24.84 ab
T_{14}	9.48 a	16.35 a	21.56 a	25.95 a
$S\bar{x}$	0.678	0.477	0.576	0.496
CV(%)	6.57	5.56	5.15	5.69

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMRT

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* (30gm kg^{-1}seed) inoculant
T_9: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30gm kg^{-1}seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30gm kg^{-1}seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30gm kg^{-1}seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30gm kg^{-1}seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

4.3 Nodules per plant

Number of nodules per plant of mungbean varied significantly due to the different treatments (Appendix V). The maximum number of nodule per plant (22.60) was recorded from T_{14} (*Rhizobium* (30gm kg^{-1}seed) + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was similar with T_{13} (*Rhizobium* (30gm kg^{-1}seed) + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_9 (*Rhizobium* (30gm kg^{-1}seed) + Urea: 45 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), respectively. Lowest number of nodules per plant (13.20) was recorded from control treatment (Fig- 1).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the development of nodule of mungbean. This trend was similar or followed by the combination of *Rhizobium* with NPK fertilizer or their combination. Different combination of NPK fertilizer followed this trend. Sole application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1992), Werakonphanit *et al.* (1979), Dost *et al.* (2004), Malik *et al.* (2006), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993).

4.4 Total dry matter per plant

Total dry matter per plant of mungbean differs significantly due to the different treatments at 20, 30, 40 and 50 DAS (Appendix V). At 20 DAS, the maximum total dry matter per plant (21.06 g) was recorded from treatment T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was similar (20.51 g) with

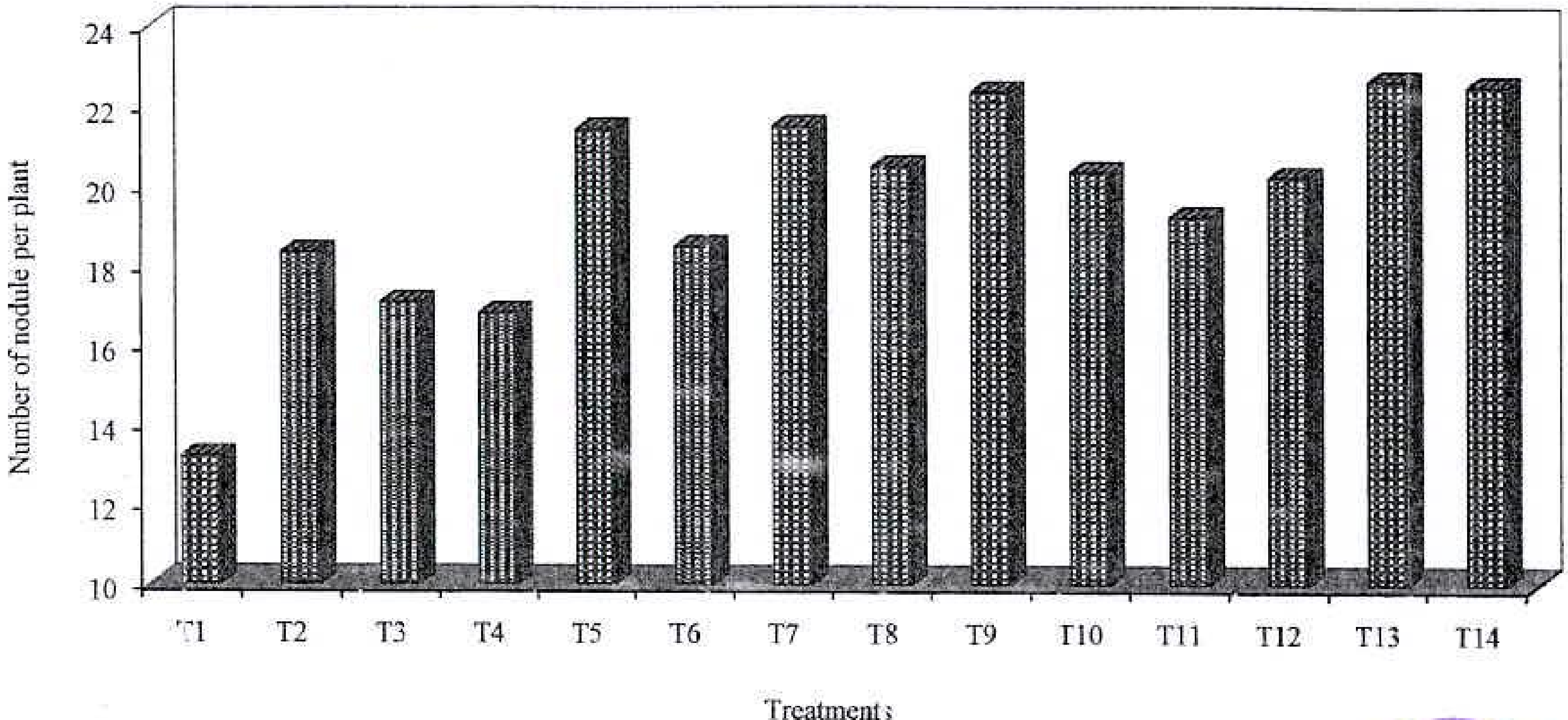

Figure 1. Effect of inoculation and fertilization on number of nodule per plant of mungbean

T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and the lowest total dry matter per plant (14.18 g) was recorded from T_1 (control) which was significantly different from other treatment combination. The highest total dry matter per plant (96.01 g) was recorded from T_{14} which was statistically similar with T_{13} (94.14 g), T_{10} (86.04 g) and T_{12} (84.16 g), while the lowest total dry matter per plant (62.36 g) was recorded from T_1 which was statistically similar with T_2 (67.49 g) and T_3 (67.84 g) at 30 DAS. At 40 DAS, the highest total dry matter per plant (207.66 g) was recorded from T_{14} which was statistically similar with T_{13} (195.65 g) and T_{12} (181.93 g). Again, the lowest total dry matter per plant (124.61 g) was recorded from T_1. The highest total dry matter per plant (330.07 g) was recorded from T_{14} which was statistically similar with T_{13} (316.44 g), T_{12} (297.52 g), T_{10} (289.10 g). On the other hand the lowest total dry matter per plant (217.78 g) was recorded from T_1 at 50 DAS. There was found to increase total dry matter with the advancement of days. There was no significant difference between treatment T_{13} &T_{14} where bio-fertilizer with TSP & MP and bio-fertilizer with urea, TSP &MP respectively. There was trend increase total dry matter with the advancement of days. There was no significant difference between treatment T_{14} and T_{13} where bio-fertilizer with TSP & MP bio-fertilizer with urea, TSP &MP respectively

Among the different combination, *Rhizobium* with recommended doses of fertilizer was more effective for the vegetative growth of mungbean which resulted highest total dry matter per plant. This trend was similar or followed by the combination of *Rhizobium* with NPK fertilizer or their combination. Recommended NPK fertilizers dose also effective for total dry matter per plant. On the other hand control treatment showed the minimum plant growth as a result lowest total dry matter per plant. Sole application of NPK fertilizer was effective than the individual one with *Rhizobium*. This findings was supported by Werakonphanit *et al.* (1979), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Khurana and Poonam (1993).

Table 3. Effect of inoculation and fertilization on total dry matter per plant of mungbean

Treatments	Total dry matter per plant (g) at			
	20 DAS	30 DAS	40 DAS	50 DAS
T_1	14.18 g	62.36 d	124.61g	217.78 e
T_2	18.51 e	67.49 cd	143.80 d-f	245.34 c-e
T_3	16.02 f	67.84 cd	143.06 ef	242.62 de
T_4	16.79 f	73.14 b-d	155.65 c-f	257.90 b-e
T_5	19.61 b-d	69.65 b-d	148.73 d-f	248.62 c-e
T_6	18.32 e	72.92 b-d	157.92 c-e	258.75 b-e
T_7	19.87 bc	73.43 b-d	153.92 c-f	260.71 b-e
T_8	18.96 c-e	68.87 cd	144.60 d-f	239.81 de
T_9	19.98 bc	66.65 d	147.67 d-f	245.34 c-e
T_{10}	19.08 c-e	86.04 ab	175.48 b-d	289.10 a-c
T_{11}	19.08 c-e	76.46 b-d	162.34 c-e	264.90 b-d
T_{12}	18.64 de	84.16 a-c	181.93 a-c	297.52 ab
T_{13}	20.51 ab	94.14 a	195.65 ab	316.44 a
T_{14}	21.06 a	96.01 a	207.66 a	330.07 a
$S\bar{x}$	0.321	5.120	9.577	13.468
CV(%)	2.98	11.72	10.35	8.79

In a column means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* inoculant
T_9: *Rhizobium* + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

4.5 Crop growth rate

Crop growth rate (CGR) of mungbean varied significantly due to the different treatments at 20-30, 30-40 and 40-50 DAS (Appendix VI). At 20-30 DAS, the highest CGR (7.49 g m^{-2} day^{-1}) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (7.36 g m^{-2} day^{-1}) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest CGR (4.82 g m^{-2} day^{-1}) was recorded from T_1 (control) which was closely followed (4.90 g m^{-2} day^{-1}) by T_2 (Urea: 45 kg ha^{-1}) (Table 4). At 30-40 DAS, the highest CGR (11.17 g m^{-2} day^{-1}) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (10.15 g m^{-2} day^{-1}) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest CGR (6.23 g m^{-2} day^{-1}) was recorded from T_1 (control) which was closely followed (7.52 g m^{-2} day^{-1} and 7.63 g m^{2} day^{-1}) by T_3 (TSP: 80 kg ha^{-1}) and T_2 (Urea: 45 kg ha^{-1}), respectively. At 40-50 DAS, the highest CGR (12.24 g m^{-2} day^{-1}) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}+MP: 55 kg ha^{-1}) which was statistically similar (12.08 g m^{-2} day^{-1}) with T_{13} (*Rhizobium*+ TSP:80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest CGR (9.32 g m^{-2} day^{-1}) was recorded from T_1 (control) which was closely followed (9.96 g m^{-2} day^{-1}) by T_3 (TSP: 80 kg ha^{-1}).

Table 4. Effect of inoculation and fertilization on crop growth rate of mungbean

Treatments	Crop Growth Rate (g $m^{-2}day^{-1}$)		
	20-30 DAS	30-40 DAS	40-50 DAS
T_1	4.82 d	6.23 e	9.32 d
T_2	4.90 cd	7.63 de	10.15 b-d
T_3	5.18 b-d	7.52 de	9.96 b-d
T_4	5.63 b-d	8.25 cd	10.23 b-d
T_5	5.00 cd	7.91 de	9.99 b-d
T_6	5.46 b-d	8.50 b-d	10.08 b-d
T_7	5.36 b-d	8.05 cd	10.68 a-d
T_8	4.99 cd	7.57 de	9.52 cd
T_9	4.67 d	8.10 cd	9.77 b-d
T_{10}	6.70 ab	8.94 b-d	11.36 a-c
T_{11}	5.74 b-d	8.59 b-d	10.26 b-d
T_{12}	6.55 a-c	9.78 a-c	11.56 ab
T_{13}	7.36 a	10.15 ab	12.08 a
T_{14}	7.49 a	11.17 a	12.24 a
$S\bar{x}$	0.504	0.531	1.612
CV(%)	15.30	10.88	9.14

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMRT

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* (30 gm kg^{-1} seed) inoculant
T_9: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30 gm kg^{-1} seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

4.6 Relative growth rate

Relative growth rate (RGR) of mungbean varied significantly due to the different treatments at 20-30 DAS but at 30-40 and 40-50 DAS did not varied significantly (Appendix VII). At 20-30 DAS, all the treatments showed almost similar RGR except treatment T_2, T_5, T_7, T_8 & T_9 respectively. It is interesting to note that control treatment showed similar to maximum RGR. Almost similar trend was followed at 30-40 and 40-50 DAS in case of RGR.

Table 5. Effect of inoculation and fertilization on relative growth rate of mungbean

Treatments	Relative growth rate (g g^{-1} day^{-1})		
	20-30 DAS	30-40 DAS	40-50 DAS
T_1	0.148 ab	0.069	0.056
T_2	0.128 cd	0.076	0.053
T_3	0.144 a-c	0.074	0.053
T_4	0.146 a-c	0.076	0.051
T_5	0.127 cd	0.076	0.051
T_6	0.138 a-d	0.077	0.049
T_7	0.130 b-d	0.074	0.053
T_8	0.128 cd	0.075	0.051
T_9	0.120 d	0.080	0.051
T_{10}	0.151 a	0.071	0.050
T_{11}	0.139 a-d	0.075	0.049
T_{12}	0.149 ab	0.078	0.050
T_{13}	0.152 a	0.073	0.048
T_{14}	0.152 a	0.077	0.046
$S\bar{x}$	0.007	0.003	0.002
CV(%)	8.39	6.74	7.58

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMTR

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* (30 gm kg^{-1} seed) inoculant
T_9: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30 gm kg^{-1} seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

4.7 Number of branches per plant

Significant variation was observed in terms of number of branches per plant due to the different treatments (Appendix VIII). The maximum number of branches per plant (8.48) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (8.21, 8.02, 7.68 and 7.63) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_{10} (*Rhizobium* + TSP: 80 kg ha^{-1}) T_5 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}) and T_9 (*Rhizobium* + Urea: 45 kg ha^{-1}), respectively. The minimum number of branches per plant (4.26) was recorded from T_1 (control) which was significantly different from other treatments (Table 6).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean, specially number of branches per plant. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. Combination NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1984), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Khurana and Poonam (1993), Sattar and Ahmed (1995).

Table 6. Effect of inoculation and fertilization on yield contributing characters of mungbean

Treatments	Branches per plant (No.)	Pod length (cm)	Seeds per pod (No.)	1000 seed weight (g)
T_1	4.26 e	4.36 c	5.87 e	17.79 de
T_2	6.87 cd	5.15 bc	7.07 cd	19.37 c-e
T_3	6.89 cd	4.69 c	6.67 de	16.80 e
T_4	6.39 d	4.87 c	6.73 d	19.35 c-e
T_5	7.68 a-c	5.82 bc	8.00 ab	21.79 b-d
T_6	7.17 b-d	5.05 c	7.07 c-d	20.37 c-e
T_7	7.17 b-d	6.37 a-c	8.13 a-b	23.75 a-c
T_8	7.17 b-d	5.39 b-c	7.67 a-c	20.20 c-e
T_9	7.63 a-d	5.71 b-c	8.07 ab	21.42 b-d
T_{10}	8.02 a-c	6.49 a-c	7.67 a-c	22.56 bc
T_{11}	7.14 b-d	6.12 bc	7.33 b-d	23.16 bc
T_{12}	6.81 cd	5.70 bc	7.53 b-d	24.86 ab
T_{13}	8.21 ab	7.74 ab	8.20 ab	25.62 ab
T_{14}	8.48 a	8.71 a	8.53 a	27.82 a
$S\bar{x}$	0.391	0.776	0.280	1.339
CV(%)	9.48	6.90	6.48	10.65

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMRT

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* (30 gm kg^{-1} seed) inoculant
T_9: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* (30 gm kg^{-1} seed) + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* (30 gm kg^{-1} seed) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* (30 gm kg^{-1} seed) + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

4.8 Number of pods per plant

Number of pods per plant of mungbean varied significantly due to the different treatments (Appendix VIII). The maximum number of pods per plant (20.87) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (19.60, 18.80, 18.67 and 18.47) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_{10} (*Rhizobium* + TSP: 80 kg ha^{-1}), T_{11} (*Rhizobium* + MP: 55 kg ha^{-1}) and T_{12} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}), respectively. Again the minimum number of pods per plant (12.20) was recorded from T_1 (control) which was closely followed (15.73) by T_3 (TSP: 80 kg ha^{-1}) (Figure 2).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative and reproductive growth of mungbean with highest vegetative growth, the maximum number of pods per plant. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. On the other hand control treatment gave the lowest plant growth with minimum number of pods per plant. Different combination of NPK fertilizer followed this trend. Application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1992), Werakonphanit *et al.* (1979), Dost *et al.* (2004), Raman and Venkataramana (2006), Malik *et al.* (2006), Nigamananda (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993).

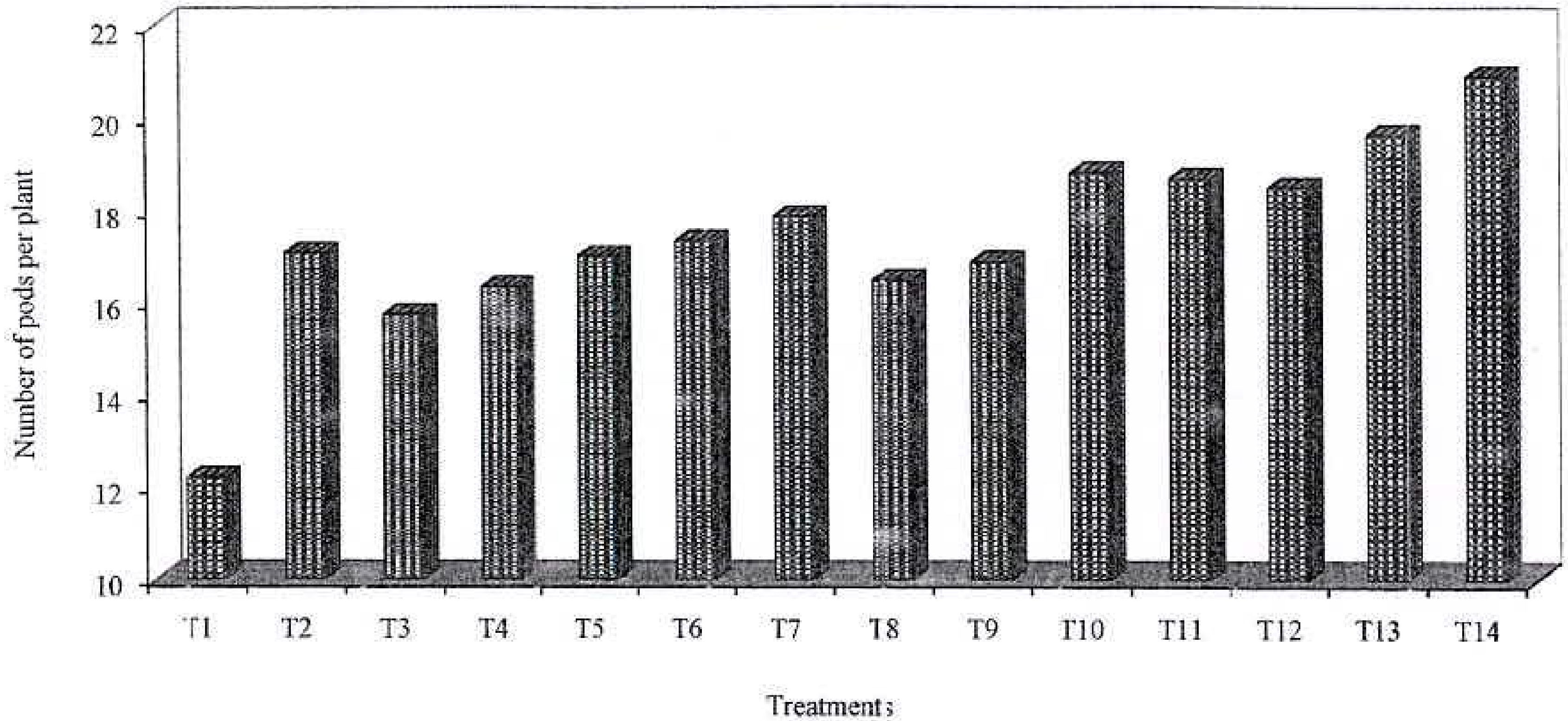

Figure 2. Effect of inoculation and fertilization on number of pods per plant of mungbean

4.9 Pod length

Pod length of mungbean differed significantly due to the application of different treatments (Appendix VIII). The maximum pod length (8.71 cm) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (7.74 cm, 6.49 cm, 6.37 cm) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_{10} (*Rhizobium* + TSP: 80 kg ha^{-1}), T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), respectively. On the other hand the minimum pod length (4.36 cm) was recorded from T_1 (control) which was statistically similar with T_3 (TSP: 80 kg ha^{-1}), T_4 (MP: 55 kg ha^{-1}) and T_6 (TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), respectively (Table 6).

For above discussion it can be said that *Rhizobium* with recommendation doses of fertilizer was more effective for the various growth parameter of mungbean for that this combination gave the highest pod length. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. On the other hand control gave minimum pod length. Different combination of NPK fertilizer followed this trend. Sole application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Khurana and Poonam (1993), Sattar and Ahmed (1995).

4.10 Number of seeds per pod

Number of seeds per pod of mungbean varied significantly due to the different treatments (Appendix VIII). The maximum number of seeds per pod (8.53) was recorded from T_{14} (*Rhizobium* (30 gm kg^{-1} seed) + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (8.20, 8.13, 8.07, 8.00 and 7.67) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg

ha^{-1}), T_9 (*Rhizobium* + Urea: 45 kg ha^{-1}) and T_5 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}) and T_8 (*Rhizobium*), respectively. Again the minimum number of seeds per pod (5.87) was recorded from T_1 (control) which was closely followed (6.67 and 6.73) by T_3 (TSP: 80 kg ha^{-1}) and T_4 (MP: 55 kg ha^{-1}), respectively (Table 6).

Among the combination of bio-fertilizer with different doses of chemical fertilizer, *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative and reproductive growth of mungbean. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. On the other hand control treatment gave the minimum number of seeds per pod. Different combination of NPK fertilizer followed this trend. Application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1992), Raman and Venkataramana (2006), Malik *et al.* (2006), Nigamananda (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Khurana and Poonam (1993).

4.11 Weight of thousand seeds

Weight of 1000 seeds of mungbean varied significantly due to the different treatments (Appendix VIII). The highest weight of 1000 seeds (27.82 g) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (25.62 g, 24.86 g and 23.75 g) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_{12} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), respectively and the lowest weight of 1000 seeds (17.79 g) was recorded from T_1 (control) which was closely followed (16.80 g) by T_3 (TSP: 80 kg ha^{-1}), T_2, (Urea: 45 kg ha^{-1}), T_4(MP: 55 kg ha^{-1}),T_6 (TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}a) and T_8 *(Rhizobium* inoculunt), respectively (Table 6).

For the above discussion it can be said that different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean for that this combination gave the maximum reproductive growth and well developed seed that leads to highest weight of 1000 seeds. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. Application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Khurana and Poonam (1993), Sattar and Ahmed (1995).

4.12 Seed yield

Significant variation was recorded for seed yield of mungbean due to the different treatments (Appendix IX). The highest seed yield (1.40 t/ha) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (1.21 t/ha, 1.19 t/ha) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest seed yield (0.59 t/ha) was recorded from T_1 (control) which was closely followed (0.69 t/ha) by T_3 (TSP: 80 kg ha^{-1}), T_2 (Urea:45kg ha^{-1}) and T_4 (MP: 45 kg $^{ha-}$1), respectively (Figure 3).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean for that this combination gave the maximum reproductive growth and well developed seed that leads to highest seed yield. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination.

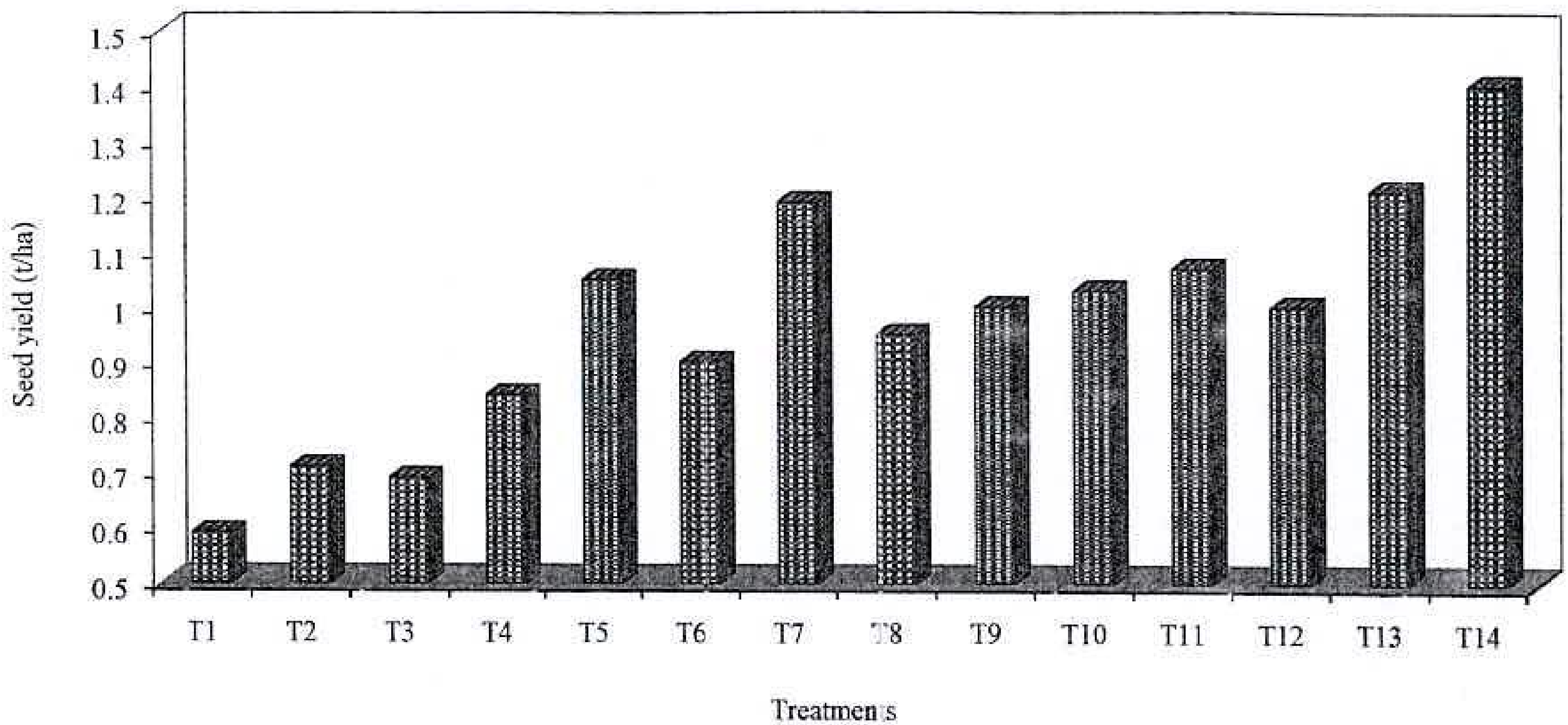

Figure 3. Effect of inoculation and fertilization on seed yield per hectare of mungbean

Sole application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1984), Werakonphanit *et al.* (1979), Dost *et al.* (2004), Duary *et al.* (2004), Bhattacharyya and Pal (2001), Shukla and Dixit (1996), Sattar and Ahmed (1995), Khurana and Poonam (1993).

4.13 Stover yield

Stover yield of mungbean varied significantly due to the different treatments (Appendix IX). The highest stover yield (3.47 t/ha) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (3.36 t/ha, 3.31 t/ha and 3.30 t/ha) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and T_{12} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1}), while the lowest stover yield (2.12 t/ha) was recorded from T_1 (control) which was closely followed (3.01 t/ha and 3.02 t/ha) by T_2 (Urea: 45 kg ha^{-1}) and T_3 (TSP: 80 kg ha^{-1}), respectively (Figure 4).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean. With highest vegetative growth ensured maximum stover yield. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. On the other hand control gave the lowest plant growth with minimum stover yield. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1992), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Khurana and Poonam (1993).

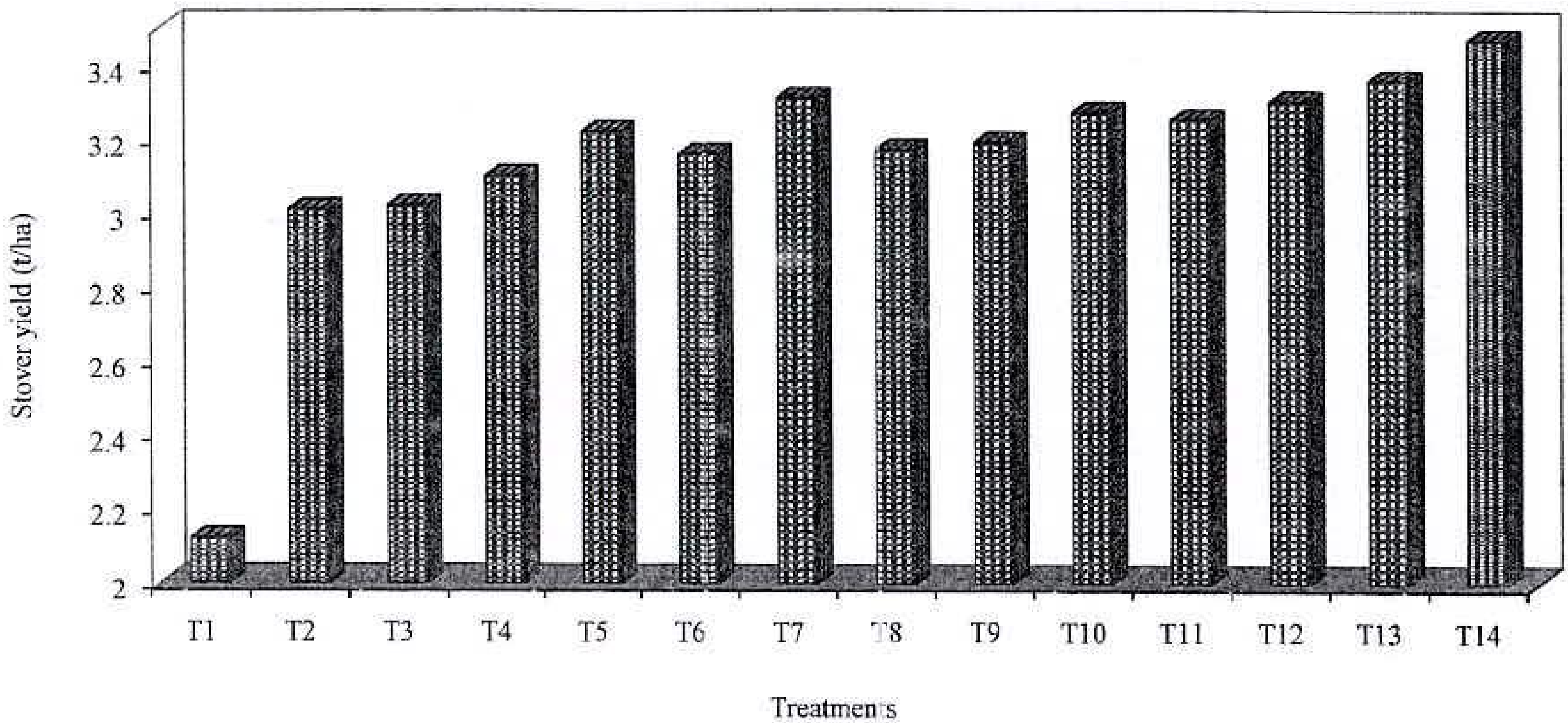

Figure 4. Effect of inoculation and fertilization on stover yield of mungbean

4.14 Biological yield

Biological yield of mungbean under the present trial varied significantly due to the different treatments (Appendix IX). The highest biological yield (4.87 t/ha) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically similar (4.56 t/ha and 4.50 t/ha) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest biological yield (2.71 t/ha) was recorded from T_1 (control) which was closely followed (3.71 t/ha and 3.72 t/ha) by T_3 (TSP: 80 kg ha^{-1}) and T_2 (Urea: 45 kg ha^{-1}), respectively (Table 7).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean. With highest vegetative growth ensured maximum biological yield. This trend was similar or followed by the combination of *Rhizobium* and only any type of NPK fertilizer or their combination. On the other hand control gave the lowest plant growth with minimum biological yield. Different combination of NPK fertilizer followed this trend. Sole application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Salimullah *et al.* (1987), Patel *et al.* (1992), Werakonphanit *et al.* (1979), Patel *et al.* (1992), Dost *et al.* (2004), Raman and Venkataramana (2006), Malik *et al.* (2006), Nigamananda (2007), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993).

4.15 Harvest index

Harvest index of mungbean varied significantly due to the different treatments (Appendix IX). The highest harvest index (28.57%) was recorded from T_{14} (*Rhizobium* + Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) which was statistically

Table 7. Effect of inoculation and fertilization on biological yield and harvest index of mungbean

Treatments	Biological yield (t/ha)	Harvest Index (%)
T_1	2.71 f	21.79 cd
T_2	3.72 e	19.05 d
T_3	3.71 e	18.59 d
T_4	3.94 de	21.18 cd
T_5	4.27 b-d	24.44 bc
T_6	4.06 de	22.12 cd
T_7	4.50 a-c	26.38 ab
T_8	4.12 cd	23.01 bc
T_9	4.19 b-d	23.77 bc
T_{10}	4.30 b-d	24.02 bc
T_{11}	4.32 b-d	24.46 bc
T_{12}	4.31 b-d	23.29 bc
T_{13}	4.56 ab	26.42 ab
T_{14}	4.87 a	28.57 a
$S\bar{x}$	0.124	1.143
CV(%)	5.20	8.47

In a column means having similar letter(s) are statistically similar at 0.05 level of probability by DMRT

T_1: Control (No fertilizer and *Rhizobium*)
T_2: Urea (45 kg ha^{-1})
T_3: TSP (80 kg ha^{-1})
T_4: MP (55 kg ha^{-1})
T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_8: *Rhizobium* inoculant
T_9: *Rhizobium* + Urea (45 kg ha^{-1})
T_{10}: *Rhizobium* + TSP (80 kg ha^{-1})
T_{11}: *Rhizobium* + MP (55 kg ha^{-1})
T_{12}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1})
T_{13}: *Rhizobium* + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})
T_{14}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1})

similar (26.42% and 26.38%) with T_{13} (*Rhizobium* + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}) and T_7 (Urea: 45 kg ha^{-1} + TSP: 80 kg ha^{-1} + MP: 55 kg ha^{-1}), while the lowest harvest index (18.59%) was recorded from T_3 (TSP: 80 kg ha^{-1}) which was statistically similar (19.05%) to T_2 (Urea: 45 kg ha^{-1}), T_1, T_4 and T_6, respectively (Table 7).

Among the different combination *Rhizobium* with recommendation doses of fertilizer was more effective for the vegetative growth of mungbean. With highest vegetative growth ensured highest harvest index. This trend was similar or followed by the combination of *Rhizobium* and only NPK fertilizer or their combination.Application of NPK fertilizer was more effective than the individual one with *Rhizobium*. This findings was supported by Werakonphanit *et al.* (1979), Patel *et al.* (1992), Dost *et al.* (2004), Raman and Venkataramana (2006), Nadeem *et al.* (2004), Rajender *et al.* (2003), Bhattacharyya and Pal (2001), Sattar and Ahmed (1995), Khurana and Poonam (1993).

Chapter 5

SUMMARY AND CONCLUSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from March to May 2007 to study the effect of inoculation and fertilization on the growth and yield of mungbean. The variety BARI mung 5 was used as the test crop. The treatments of the experiment were as T_1: Control (No fertilizer and *Rhizobium*), T_2: Urea (45 kg ha^{-1}), T_3: TSP (80 kg ha^{-1}), T_4: MP (55 kg ha^{-1}), T_5: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}), T_6: TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1}), T_7: Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1}), T_8: *Rhizobium* inoculant, T_9: *Rhizobium* + Urea (45 kg ha^{-1}), T_{10}: *Rhizobium* + TSP (80 kg ha^{-1}), T_{11}: *Rhizobium* + MP (55 kg ha^{-1}), T_{12}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}), T_{13}: *Rhizobium* + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1}) and T_{14}: *Rhizobium* + Urea (45 kg ha^{-1}) + TSP (80 kg ha^{-1}) + MP (55 kg ha^{-1}). Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield were recorded.

Plant height and number of leaves per plant of mungbean varied significantly for different treatment. At 20 DAS, the tallest plant (36.81 cm) was recorded from T_{14} and the shortest (19.33 cm) was recorded from control treatment. Similar trend was observed at 30, 40 and 50 DAS respectively. At 20 DAS, the maximum number of leaves per plant (9.48) was recorded from T_{14} and the lowest (4.78) was recorded from T_1. The maximum number of leaves per plant (16.35) was recorded from T_{14} and the minimum (12.87) was recorded from T_1 at 30 DAS. At 40 DAS, the maximum number of leaves per plant (21.56) was recorded from T_{14} and the minimum (16.11) was recorded from T_1. The same trend was followed at 50 DAS. There was trend to increase leaves per plant with the advancement of days.

The maximum number of nodules per plant (22.60) was recorded from T_{14} and the minimum (13.20) was recorded from T_1. Maximum total dry matter per plant was recorded from treatment T_{14} where bio-fertilizer and recommended chemical fertilizer used but clearly followed by bio-fertilizer without urea. Besides, only fertilizer application singly showed lower nodules per plant.

There was trend to increase crop growth rate with the advancement of days and maximum from 40-50 DAS. There was no significant difference between treatments T_{14} & T_{13} where rhizobium used in both treatments but in later urea was omitted.

Yield attributes such as branches/plant, pods/plant, length of pod and seeds/pod was recorded maximum from the treatments comprise rhizobium with NPK or PK fertilizer combination. Similar trend was also found where rhizobium with only urea or TSP or TSP &MP combination. But single application of urea or TSP or MP showed similar trend with no fertilizer which lowest yield attributes were found. Seed weight also showed similar behave but only TSP application produced lower seed weight but at per to control treatment.

Seed yield showed maximum yield from bio-fertilizer & NPK combination which was clearly followed by bio-fertilizer with PK and NPK fertilizer combinations. Seed yield reflected by the treatment as per yield attributes. Stover yield also followed similar pattern as in seed yield.

From the above discussion it is found that urea could be substituted by the rhizobium but P & K need to be applied for higher seed yield.

The following suggestion may be gives from the study:

1. Growth and yield parameters of mungbean influenced by different treatments specially rhizobium with PK fertilizer.

2. Mungbean could be grown with rhizobium (30 $gmkg^{-1}$ seed) and 80 kg/ha TSP and 55 kg/ha MP for higher seed yield

3. If inoculum or rhizobium is not available, for that reason Urea (45kg/ha), TSP (80kg/ha) and MP (55kg/ha) per hectre may be used for higher yield of mungbean.

4. Only rhizobium is not sufficient for higher seed yield, but TSP and MP needs to be applied.

5. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for refine and validation of technology.

6. Cost benefit analysis should be done before recommendation.

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APPENDICES

Appendix I. Physical and chemical characteristics of initial soil (0-5 cm depth) before seed sowing

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Drainage	Well drained
Cropping pattern	Winter Vegetable – Summer Vegetable

B. Physical and chemical properties of the initial soil

Characteristics	Value	Critical value
Partical size analysis		-
Sand	27%	-
Silt	43%	-
Clay	30%	-
Textural class	silty-clay	-
pH	5.6	acidic
Organic carbon	0.45%	-
Total N	0.03%	-
Available P	20.00 ppm	-
Exchangeable	0.10 me/100 g soil	-
Available S	45 ppm	-

Source: SRDI, 2007

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from March to May 2007

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
March, 2007	31.4	19.6	54	11	8.2
April, 2007	33.6	23.6	69	163	6.4
May, 2007	34.7	25.9	70	185	7.8

* Source: Bangladesh Meteorological Department (Climate and weather division) Agargaon, Dhaka - 1212

Appendix III. Analysis of variance of the data on plant height of mungbean at different DAS as influenced by inoculation and fertilization

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm)			
		20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	2.517	0.589	20.432	20.452
Treatment	13	72.448**	93.979**	215.406**	343.914**
Error	26	10.099	17.733	27.454	46.050

**: Significant at 0.01 level of probability

Appendix IV Analysis of variance of the data on number of leaves per plant of mungbean as at different DAS influenced by inoculation and fertilization

Source of variation	Degrees of freedom	Mean square			
		Number of leaves per plant			
		20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	1.407	0.008	0.088	0.927
Treatment	13	6.265**	2.097**	4.590**	7.739**
Error	26	1.390	0.683	0.996	0.738

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on number of nodules per plant and total dry matter per plant of mungbean as influenced by inoculation and fertilization

Source of variation	Degrees of freedom	Mean square				
		Number of nodule per plant	Total dry matter per plant (g) at			
			20 DAS	30 DAS	40 DAS	50 DAS
Replication	2	7.549	0.397	24.166	163.391	547.136
Treatment	13	21.072**	10.240**	328.483**	1533.70**	3007.28**
Error	26	1.986	0.309	78.642	275.127	544.138

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on crop growth rate of mungbean as influenced by inoculation and fertilization of mungbean

Source of variation	Degrees of freedom	Mean square		
		Crop Growth Rate (g $m^{-2}day^{-1}$)		
		CGR (20-30 DAS)	CGR(30-40 DAS)	CGR (40-50 DAS)
Replication	2	0.291	0.859	1.211
Treatment	13	2.684**	4.651**	2.608**
Error	26	0.762	0.846	0.923

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on relative growth rate of mungbean as influenced by inoculation and fertilization

Source of variation	Degrees of freedom	Mean square		
		Relative growth rate (g g^{-1} day^{-1})		
		RGR (20-30 DAS)	RGR(30-40 DAS)	RGR (40-50 DAS)
Replication	2	0.0001	0.0001	0.0001
Treatment	13	0.001**	0.0001	0.0001
Error	26	0.001	0.0001	0.0001

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on yield contributing characters of mungbean as influenced by inoculation and fertilization

Source of variation	Degrees of freedom	Mean square				
		Branches per plant (No.)	Number of pods per plant	Pod length (cm)	Seeds per pod (No.)	1000 seed weight (g)
Replication	2	0.639	0.127	1.138	0.035	4.202
Treatment	13	3.084**	12.498**	4.254**	1.597**	28.651**
Error	26	0.458	3.699	1.807	0.234	5.380

**: Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on yield of mungbean as influenced by inoculation and fertilization Effect of inoculation and fertilization on yield of mungbean

Source of variation	Degrees of freedom	Mean square			
		Seed yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Harvest Index (%)
Replication	2	0.002	0.003	0.008	0.297
Treatment	13	0.144**	0.305**	0.781**	22.793**
Error	26	0.019	0.010	0.046	3.917

**: Significant at 0.01 level of probability